Describing growth pattern of selected Kedah-Kelantan cows using non-linear regression models

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Abstract

The objective of this study was to evaluate the best fit non-linear regression model to describe the growth pattern of Kedah–Kelantan (KK) cows. Estimates of asymptotic mature weight, rate of maturing and constant of integration were derived from Brody, von Bertalanffy, Gompertz and Logistic models which were fitted to cross-sectional data of body weight taken from 81 KK cattle with the age ranging from birth to 96- mo old. Coefficient of determination (R^2) and residual mean squares (MSE) were used to determine the best fit model in describing the growth pattern of KK cows. Von Bertalanffy model showed the best goodness of fit as explained by its highest R^2 and lowest MSE (0.9686 and 720.9, respectively), followed by Gompertz (0.9681 and 733.6, respectively), Logistic (0.9667 and 766.8, respectively) and Brody (0.8683 and 793.2, respectively). The correlation between rate of maturing and mature weight was found to be negative in the range of -0.7154 to -0.9213, indicating that animals of heavier mature weight had lower rate of maturing. The use of non-linear model could summarize the weight-age relationship into several biologically interpreted parameters compared to the entire lifespan weight-age data points that are difficult to interpret. The study of growth pattern also important to determine the optimum weight and age for replacement heifer and slaughter besides to strategize the feeding regime for maximum productivity.

Keywords: growth pattern, body weight, Kedah-Kelantan cows

Introduction

Kedah-Kelantan (KK) cattle contributed approximately 85% of the total beef cattle population in Malaysia (Johari and Jasmi, 2009; DVS). Devendra *et al.* (1973) reported that these cattle are stabilized crossbred of mixed Shorthorn type x Zebu ancestry. It is small sized cattle breed ranging in mature weight from 300 to 312 kg and 229 to 240 kg in male and female, respectively (Johari and Jasmi, 2009). KK cattle also have high fertility rate (Tan *et al*., 1985) and the ability to bear a calf a year (Clayton, 1983). In addition, it is also extremely hardy, well adapted to local environment and tolerant to ticks and internal parasites. In spite of its high fertility and adaptability, the growth rate which is an economic trait is considered low. The birth, weaning and yearling weights of KK cattle were 15.4 kg, 76.8 kg and 97.5 kg, respectively (Dahlan, 1985). In order to increase these productivity traits, a crossbreeding programme was carried out to increase the productivity by combining the desirable traits of two or more breeds and taking the advantage of heterosis (Johari and Jasmi, 2009). The KK cows were crossed to Brahman, Hereford and Friesian sire breeds by artificial insemination. Similar crossbreeding schemes have now became popular among farmers and various breeds such as Limousin, Droughmaster, Charolais and Belgian Blue frozen semen were introduced to KK cows to achieve higher productivity traits. However, due to the popularity and farmers' preferences towards artificial insemination program using European breeds, the number of KK cattle long considered as national bovine genetic resources is declining annually. Realizing this threatening situation, MARDI has started the initiative to restore and improve the KK cattle genetic resources by breeding and selection programme.

Growth plays a significant role to ensure the sustainability of a beef cattle operation alongside reproductive efficiency, thus it is an important criterion to emphasize in animal selection. Growth is defined as The net accretion of protein and fat in respective tissues controlled by nutrition, environment and the genetic capacity to grow (Breever *et al.,* 1992). It is important to understand the animals' growth in order to decide the optimum age and body weight to breed and slaughter. Furthermore, strategic feeding management can then be implemented to achieve the desired body weight without adding too much cost.

However, the study of growth often takes a long period; therefore non-linear algebraic models are used widely in order to describe the growth events of the animals. Non-linear algebraic model is an effective method of describing individual growth pattern in a small number of biologically interpretable parameters. Such models tend to reduce the effect of temporary environment and random variation as well as adjusting for the non-linear relationship between age and live weight or body size (Berry *et al.,* 2005). Relative and absolute growth rates, maturing rate, and mature size are the important growth parameters that can be estimated by using growth functions (Kaps *et al.,* 2000). Sigmoidal growth curve is often characterized by an increasing slope, named the self-accelerating phase and a segment of decreasing slope of the self-inhibiting phase (Goonewardene *et al.,* 1981). The meeting point between these two phases is known as the point of inflection where the peak accelerated growth tends to decline towards a growth plateau. Studies in animals' growth by using growth models were reported in goats (Ariff *et al.,* 2010), sheep (Topal *et al.,* 2004; Jimenez-Severiano *et al.,* 2010; da Silva *et al.,* 2012), beef cattle (Kaps *et al.,* 2000; Freetly *et al.,* 2011), dairy cattle (Perotto *et al.,* 1992; Berry *et al.,* 2005), chicken (N'dri *et al.,* 2006), mouse (Koops *et al.,* 1987; Kurnianto *et al.,* 1999) and pig (Koops and Grossman, 1991). The objective of this study was to determine the best fitted non-linear model to estimate the mature weight and growth curve parameters of KK cattle.

Materials and Methods

Cross sectional data of body weight were collected from 81 female KK cattle (age ranged from birth to 96 mo) using a digital weighing scale in MARDI Kemaman. The age of the animal was determined from farm records where date of birth and date of weighing were available.

Four nonlinear models, namely Brody, Gompertz, von Bertalanffy and Logistic, were fitted to the KK body weight dataset to determine the growth pattern. These models are determined by the three parameters of A, k and b representing the asymptote, rate of growth towards maturity and integration constant, respectively. These 3-parameter growth models were chosen for their ease of calculation and biological interpretation of the model parameters (Brown *et al.*, 1976). The four growth models used were described in Table 1 as suggested by Malhado *et al*. (2009)

Table 1. Non linear models equations for growth curve parameters fitting and their point of inflection

Model	Equation	Point of inflection
Brody	$Y_t=A(1-Be^{-kt})$	-
Gompertz	$Y_t=Ae^{-Be^{-kt}}$	0.368*A
von Bertalanffy	$Y_t=A(1-Be^{-kt})^3$	0.296*A
Logistic	$Y_t=A/(1+Be^{-kt})$	A/2

where Y_t is the observed measurement of size, at age t in mo, A is the asymptote for the measure of size, B is constant of integration and k is rate of maturing per day interpreted as daily rate of growth relative to asymptotic size. The coefficient of determination (R^2) and residual mean square (MSE) were used to determine the model with the highest goodness of fit to describe the growth pattern for body weight in KK cows. A model which yields higher R^2 and lower MSE is considered a better fit model since it could explain a higher proportion of the variability in body weight than a model with lower R^2 and higher MSE (Malhado *et al*., 2009).

Results and Discussion

The growth curve parameters for body weight as derived from Gompertz, Brody, von Bertalanffy and Logistic models for KK cows are presented in Table 2. Based on the coefficient of determination, the von Bertalanffy model showed the highest R^2 value and presented the best goodness of fit reaching up to 96.8 % while the Brody model was least fitted for the dataset to estimate the KK cow mature weight based on its lowest value of R^2. Supported by lowest MSE, the von Bertalanffy model was the best model to describe the body weight of KK cows followed by Gompertz and Logistic models. A similar study was done by Lopes *et al.* (2012) on Nellore cattle, but the R^2 rank for the models fell in the order of von Bertalanffy, Logistic, Brody and Gompertz. Gbangboche *et al.* (2011) ranked Brody, Gompertz and Logistic in the study of growth curve of live body weight in Lagune cattle as shown by the highest R^2 and lowest MSE. Hafiz *et al.* (2015) reported that the rank of non-linear models was Logistic, Gompertz, von Bertalanffy and Brody in female Brakmas cattle. It indicates that different datasets, breeds and environmental factors could yield different goodness of fit for the models. It is supported by a study by Malhado *et al*. (2009) where same functions may vary in results based on breed, population and features tested.

The estimated mature weights derived by all models ranged from 239.1±5.769 to 255.4±9.005 kg. The Brody model gave the highest estimated mature weight for KK cattle of 255.4±9.005 kg while Logistic model yielded the lowest estimates of mature weight at 239.1±5.769 kg. A similar trend was found by Perotto *et al.* (1992) for dairy cattle, Malhado *et al*. (2009) for crossbred Dorper sheep and Gbangboche *et al.* (2011) for beef cattle, where the Brody model yielded higher estimate of mature weight compared to the other models. A study by Hamouda and Atti (2011) also showed Brody model estimated the highest mature weight and several fat tail characteristics namely lower fat tail circumference, lower fat tail width and fat tail length in Barbarine sheep. The range of mature weight for KK cattle raised in MARDI Kemaman was higher than those reported by Ariff *et al.* (1993) and Devendra *et al.* (1973), where the mature weight 227.8±2.30 kg and 173.7 kg, respectively. The variation of body weight reflected the impact of environmental factors and management system, particularly the nutrition (Entwistle *et al.*, 2012).

For the rate of maturing, Brody model showed the lowest maturing rate at 0.0251±0.004 while Logistic model gave the highest estimate of the parameter k at 0.0520±0.005. Animals with high maturing rate will attain its mature weight earlier than the animals with low rate of maturing. Cows with higher mature weight will also take a longer time to attain its mature weight as reflected in their lower rate of maturing (Kratochvílová *et al.*, 2002; Fitzhugh, 1976), therefore the animals are older at the time of maturity than the animals with lower mature weight. The rate of maturing of KK cattle was found low when compared to Brakmas (0.05±0.007) and Bali cattle (0.05±0.003) as reported by Hafiz *et al*. (2015) and Hafiz *et al.* (2016), respectively, but higher than the study done by Ariff *et al.*, (1993) at 0.0523±0.0037. The reduced in rate of maturing might be due to the influence of other breed that has been introduced to KK cattle all over the years. Ariff *et al.* (1993) reported that Hereford-KK, Brahman-KK and Friesian-KK showed lower rate of maturity compared to pure KK itself. This finding also agreed to the studies done previously where the animal with slow maturing rate will have bigger size at maturity as the present study on KK cattle yielded higher mature weight compared to previous study on the same breed.

The correlation between mature weight and maturing rate are the most important biological relationship in a function (McManus *et al.*, 2003). The correlation coefficients between parameter A and k were negative for all models which ranged from -0.7154 to -0.9213 with Brody model gave the highest negative correlation (-0.9213). These highly negative correlation coefficients between the parameter k and the estimate of mature size A estimated by Brody model in KK cattle are found to be similar to those of Brakmas cattle (Hafiz *et al.*, 2015). Brown *et al*. (1976) explained that the larger estimate of mature weight is associated with smaller rate of maturing. For beef cattle producer, it is very important to have animals with fast maturing rate as it will reflect the earliness of the animals to be used for breeding cows and for slaughtering purpose. Malhado *et al.* (2009) reported that Dorper x Santa Ines sheep were possible to be slaughter earlier as it has faster growth compared to Doper x Rabo Largo and Dorper x Morada sheep. Difference in rate of maturing will also reflect to the age at puberty and it is important to determine the life time productivity of a cow (Smith *et al.*, 1976).

Table 2. Estimates of growth curve parameters from Gompertz, Brody, von Bertalanffy and Logistic models, coefficients of determination and residual mean square for body weight in KK cows

Model	Growth curve parameter[1]			r	R^2	MSE
	A (kg)	b	k			
Gompertz	244.5±7.103	1.405±0.049	0.038±0.043	-0.8304	0.9681	733.6
Brody	255.4±9.005	0.802±0.014	0.025±0.004	-0.9213	0.8683	793.2
von Bertalanffy	247.2±7.796	0.385±0.011	0.033±0.004	-0.8637	0.9686	720.9
Logistic	239.1±5.769	2.678±0.159	0.052±0.005	-0.7154	0.9667	766.8

[1]A estimated mature size; b constant of integration; k rate of maturing; r the correlation of A and k; R^2 coefficient of determination; MSE residual mean square

Growth patterns of KK cattle as derived by Gompertz, von Bertalanffy, Brody and Logistic model are presented in Figure 1. From the graph, all models met the interception point at 96 mo and still showing the increasing trend until maturity. Comparing these four models, Gompertz and Brody models estimated the KK cattle will attain its maturity at the age of 16-year old, while 14-year and 11-year old for von Bertalanffy and Logistic model, respectively.

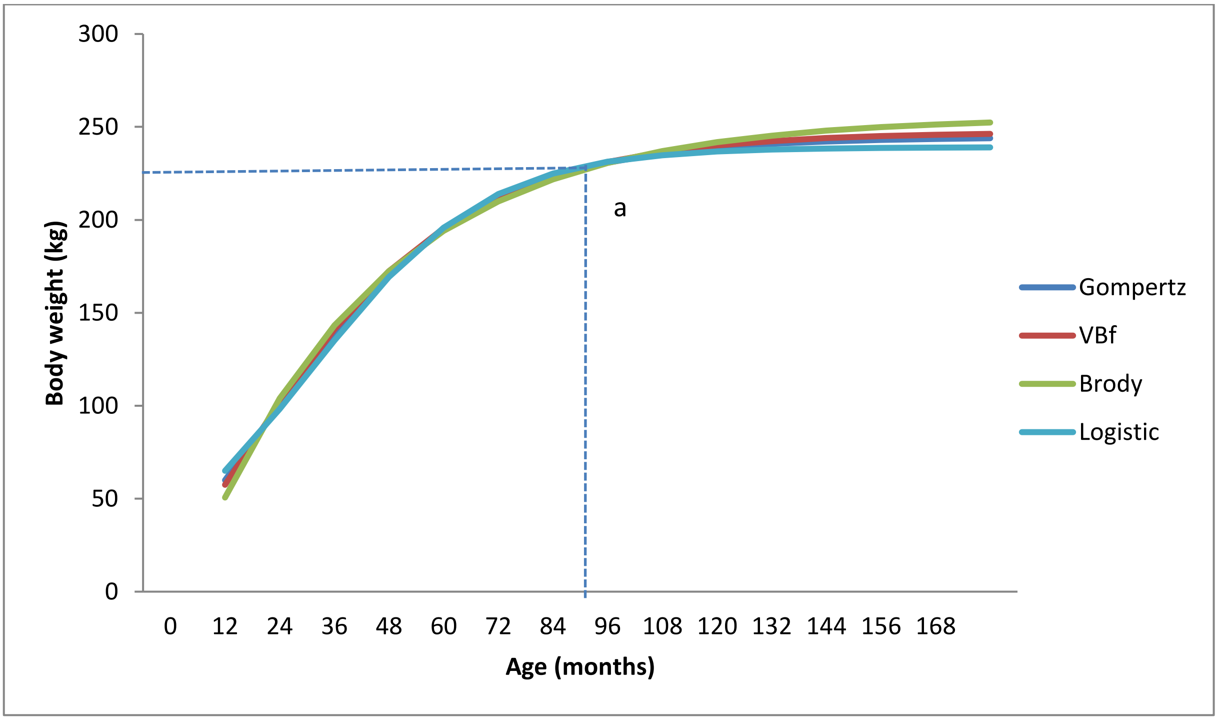

Figure 1. Growth patterns of KK cows estimated by Gompertz, von Bertalanffy (vBf), Brody and Logistic models; a=the interception point for all models

Conclusion

Three out of four non-linear models showed high representative for the KK cattle dataset where von Bertalanffy, Gompertz and Logistic accounted 96% of the dataset. Von Bertalanffy model showed the best model to describe the growth curve of KK cattle as indicated by the highest R^2 and lowest MSE values. The correlation between mature weight and rate of maturing was found to be negative and this inverse correlation indicates that animals with lower rate of maturing tend to be heavier at maturity and take longer time to attain their mature weight. The KK cattle showed slight improvement in term of mature weight compared to previous study even after years of being neglected. The study of growth curve is important in order for the animal breeders to decide the optimum body weight and age for heifer replacement and ideal weight to slaughter for maximum profit.

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